

**Lund Institute of Technology
Department of Building Acoustics**

**STUDIES OF
SOUND INSULATION
PROBLEMS
IN DIFFERENT
CONSTRUCTION
ELEMENTS
ON ACOUSTIC
ADAPTATIONS**

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STUDIES OF SOUND INSULATION PROBLEMS
IN DIFFERENT CONSTRUCTION ELEMENTS
ON ELASTIC FOUNDATIONS

av

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Abstract Two different sound insulation problems in building acoustics are considered. The first problem concerns transmission of structure-borne sound in the horizontal direction between concrete slabs, coupled with an elastic layer. In practice the displacements on each side of the elastic layer are prevented to a certain degree by reinforcing beams and extra lateral loads. We present and discuss the existing theoretical solutions and develop solutions for our junction of a combined elastic layer and reinforcing beams. The problem is first treated in one dimension (beams), but then extended to include oblique incidence of bending waves in two dimensional plates. An experimental study of the transmission loss for different types of elastic interlayers is also presented. The second problem concerns the sound insulation properties of floating floors. The theoretical work is divided into three parts, and in each part different theoretical models are studied. In the first part we consider the model of locally reacting floors. In the second part we consider resonant transmission, and in the third part the elastic interlayer is treated as a wave medium. An alternative calculation method is presented for locally reacting floors, using spatial Fourier transforms. This method is then extended to include the wave medium behaviour of the elastic interlayer. Existing solutions for the resonant transmission are presented, discussed and developed. Finally an experimental study of the sound insulation improvement is presented.		
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The thesis comprises this summary and the following two reports:

I. Transmission of Structure-borne Sound at Various
types of Junctions with Thin Elastic Layers.

Lund Institute of Technology,
Department of Building Acoustics,
Report TVBA-3016,
Lund 1984.

II. Sound Insulation Improvement of Floating Floors.

A Study of Parameters.

Lund Institute of Technology,
Department of Building Acoustics,
Report TVBA-3017,
Lund 1984.

INTRODUCTION

The thesis consists of studies of two different sound insulation problems in building acoustics. A common factor for the two cases is the fact that both have construction elements resting on elastic foundations. In the first report we consider the case of two concrete slabs, horizontally coupled with a thin elastic layer. In the second report we consider the case of a structural slab carrying an elastic layer as a foundation for a floating floor. Thus it is a vertical coupling of two plates.

THE HORIZONTAL COUPLING (Report I)

Several years ago, sound insulation problems suddenly appeared in a certain type of Swedish terrace houses. The houses had been built for years without this type of problems, but problems appeared, when the building method was changed slightly.

The floor slabs were previously cast directly on the ground, usually with expanded clay (Leca) as a foundation. This building method gave moisture problems in the slabs, so it was modified and the slabs cast on top of a thermal insulating material. This measure prevents capillary suction from the ground beneath and provides good thermal insulation properties.

However, by isolating the slabs from the ground in this way, they cannot get rid of their sound energy as easily as before. Their "acoustic temperature" is raised. This makes the coupling to the neighbouring slabs more critical and increases the risk of sound transmission between apartments through the floors.

In the summer 1979 the following interesting case was measured, when controlling whether a certain type of houses fulfilled the building code regulations regarding sound insulation:

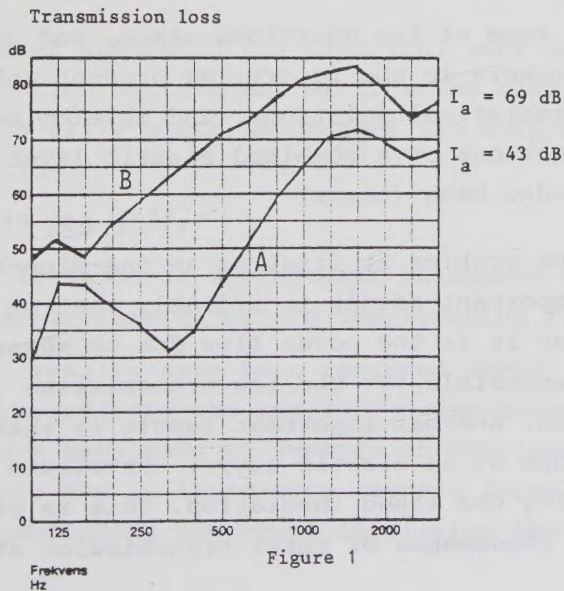
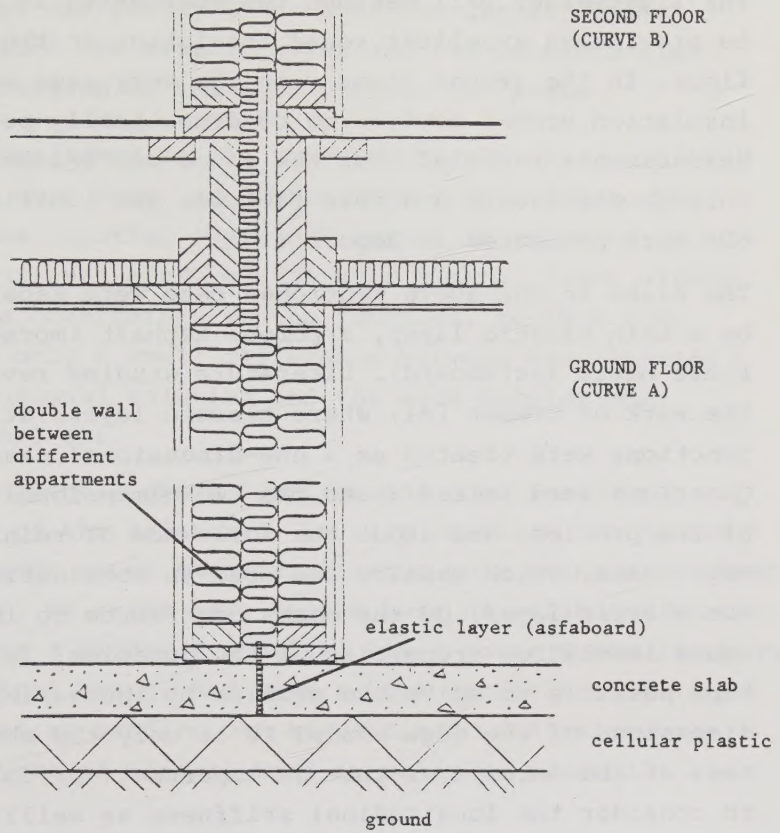
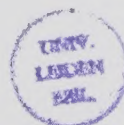


Figure 1. (From [1].)



The lightweight wall between two apartments is shown to provide an excellent sound insulation in the second floor. In the ground floor with the very same wall, the insulation proved however to be dramatically poor. Measurements revealed that the sound was transmitted through the floor, and this fact was the ignition to the work presented in Report I.

The slabs in the above mentioned case were separated by a thin elastic layer, a porous asphalt impregnated fibre board (asfaboard). Literature studies revealed the work of Cremer [2], where elastic layers at plate junctions were treated as a one-dimensional case. Questions were raised about the two-dimensional solution of the problem, and about the influence of reinforcing edge beams, which usually are used in combination with the elastic layer. Do the beams contribute to improved sound insulation properties of the junction? Is it perhaps possible to solve the problem by increasing the dimensions of the edge beams? Is it only the shear stiffness of the interlayer that is important, or do we have to consider the longitudinal stiffness as well? What kind of interlayers give the best results?

These were some of the questions asked, and we try to give the answers in the report. We present and discuss existing theoretical solutions, and develop solutions for our junctions of a combined elastic layer and a reinforcing edge beam (beams).

We treat the problem at first as an one-dimensional case. The most important result is probably that we show clearly that it is the power flow due to shear forces that is responsible for the low transmission loss at the junction. Another important result is that edge beams on both sides of an elastic layer, contribute very little to increasing the sound insulation. This is partly because of a phenomenon of total transmission at a certain

frequency, and partly because of the larger contact area between the elastic layer and the concrete elements, compared to the case without the beams.

This is confirmed in the two-dimensional study, which shows an even less insulation improvement due to the edge beams. Another important result is achieved in the two-dimensional study of the thin elastic layer without any extra constraints at the junction. We show that there is only a small difference between the averaged two-dimensional solution and the much simpler one-dimensional one.

The experimental study confirms the poor insulation capacity of the asfboard. It also confirms the theoretical result about the transmission only being of a shear character. We refer here to the case of asfboard strips, which have a higher E-modulus, but a lower G-modulus than the original board, and have a much higher transmission loss. Similar results can be obtained with relatively thick layers of mineral wool or cellular plastic.

THE VERTICAL COUPLING (Report II)

In 1952 Cremer published his classical work on the sound insulation improvement of floating floors (later published in [2]), where he deduces the surprisingly simple result

$$\Delta L \approx 40 \log (f/f_0) \quad (1)$$

(f_0 is the fundamental spring-mass resonance frequency of the elastic interlayer and the floating floor.)

Ever since, results have been reported where (1) is shown to overestimate the insulation improvement. Many attempts have been made to improve or complement the above theory, and in literature several formulas can be found for predicting the sound insulation improvement.

These formulas are seemingly very different and give a large variation in their predictions, but still most of them are confirmed with measurements! There are obviously some configurations with such properties that the measured results agree with the most optimistic prediction formulas, while others have properties that give much lower results.

The ignition to the work presented in Report II may be said to be the discrepancy of the following two figures (fig 2 and fig 3). The first one shows measurement results reported by Cremer in [2], where the curve from (1) has been drawn for comparison. The agreement is seen to be rather good, at least for the asphalt floor:

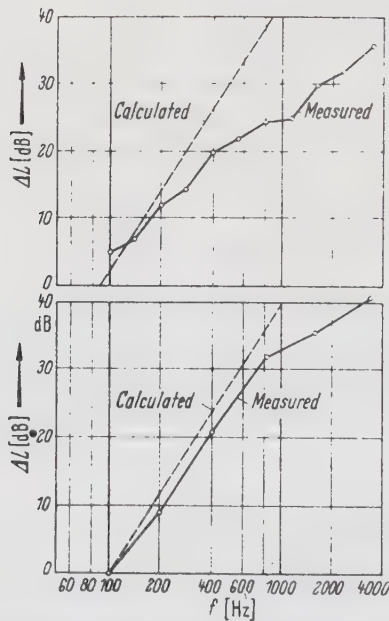


Fig.V/42. Increase in impact sound attenuation produced by floating floors. Top: 3.5 cm thick concrete floating floor, atop glass fiber mat (1000 g/m) on 13 cm thick reinforced concrete primary floor; bottom: 2.5 cm thick asphalt floating floor, atop glass fiber mat (1000 g/m) on 5 cm thick concrete floor with 20 cm deep ribs in both directions.

Figure 2. (From [2].)

The second figure is due to Ljunggren [3], where three measurement results are compared to (1). The agreement is not very good to say the least:

Figur 4. Beräknad isoleringsförbättring (—) och uppmätt (----, -.-.-, -.-.-).

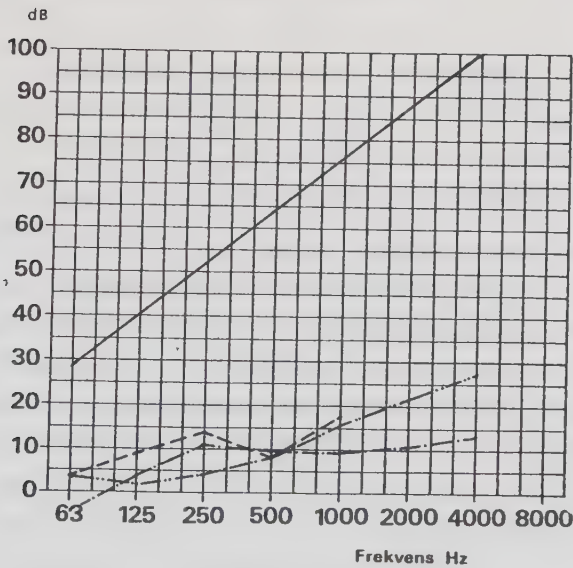
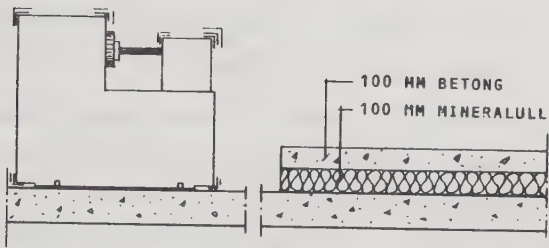


Figure 3. (From [3].)

The theoretical considerations in the report are divided into three parts, and in each part different theoretical models are studied. In the first part locally reacting floors are discussed, and here (1) is applicable. In the second part resonantly reacting floors are treated, which may be described by (1) complemented with a correction term. In the third part the influence of the interlayer as a wave medium is considered.

In the report it is shown that the different solutions of the existing theoretical work are not necessarily contradictory. Each case is just applicable to specific values of the different parameters.

Finally an experimental study of the sound insulation study is presented, where the influence of different parameters is studied. The different material properties are also measured or estimated, and theoretical and experimental results for the sound insulation improvement are compared.

The cases in the two figures above (fig 2 and 3) can be explained qualitatively by the considerations presented in the report.

The lower curve in fig 2 represents a floor with high inner losses and a stiff interlayer. The resonant transmission can be neglected, and the improvement curve follows (1) (40 dB/decade) up to a break frequency. Above this break frequency the curve has a different slope (20 dB/decade) because of the wave medium character of the interlayer. The upper curve in fig 2 has similar tendencies, but here we have also the resonant transmission to consider. Thus the break point does not appear as clearly here and the improvement is reduced, especially above f_c .

The case in fig 3 may be explained by first pointing out that because of the unlinear properties of the

mineral wool, we have a higher dynamic stiffness than the one assumed in the figure. This leads to values of equation (1) that lie 12 - 15 dB lower than the expected values in fig 3. Secondly the mineral wool layer is so thick, that we would expect the wave medium solution to be valid over just about the entire frequency region. (20 dB/decade slope). Thirdly as the structural slab is unconstrained at the edges of the floating one, we have a large influence from resonant transmission above the relatively low critical frequency, f_c .

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